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PEDIATRIC FOCUS

Extent of overweight among US children and adolescents from 1971 to 2000

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CONTEXT: The prevalence of overweight (OW) among children in the United States has increased during the last three decades, but prevalence measures fail to reveal the extent to which OW children exceed the OW threshold.
OBJECTIVE: To measure the amount by which OW children exceed the OW threshold. To examine the trend in this measure over the last three decades using data with measured weights and heights.
DESIGN, SETTING AND PARTICIPANTS: Data used for analysis are from the National Health and Nutrition Examination Survey (NHANES) for persons between 2 and 19 y of age from 1971 to 2000. Anthropometric measures were obtained by trained health technicians, and the sample sizes range from 4037 in 1999–2000 to 10 590 in 1988–1994.
MAIN OUTCOME MEASURE: The extent of OW is measured as the average amount by which each child's body mass index (BMI) exceeds their age and gender-specific OW threshold. This measure is examined by sex, age group and race/ethnicity. The OW threshold for those aged 2–19 y is defined as at or above the 95th percentile of the sex-specific BMI for age growth charts.
RESULTS: The extent of child OW has been increasing faster than the prevalence of child OW for all classifications considered in this paper, including the analysis by age, sex, race and ethnicity. The prevalence of OW for children aged 2–19 y increased by 182% between 1971–1971 and 1999–2000, while the extent of OW increased by 247% over the same time period.
CONCLUSIONS: Unlike prevalence measures, the measure of the extent of child OW is sensitive to changes in the BMI distribution of the overweight. This analysis reveals that not only have more children become OW in the last three decades, but OW children have been getting heavier.
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Introduction

Data from the 1999–2000 National Health and Nutrition Examination Survey (NHANES) indicate that the overweight (OW) prevalence in US children and adolescents has continued to increase through the 1990s.[1] OW prevalence for children between the ages of 2 and 19 y was 10% in 1988–1994 (age-adjusted to 2000 Census population estimates) and this increased to 14.4% by 1999–2000. OW children face increased risk of morbidity from coronary heart disease, hypertension and diabetes mellitus;[2–4] and children who are OW are more likely to become OW adults.[5,6] Owing to the increasing prevalence of both child and adult OW, the Surgeon General reports that being OW could soon overtake tobacco usage as the primary cause of preventable death in the United States.[7,8]

A child or adolescent is considered OW if their body mass index (BMI, defined as weight in kilograms divided by the square of height in meters) is at or above the 95th percentile of the revised 2000 Center for Disease Control (CDC), sex-specific BMI for age growth charts.[9] The CDC growth charts for children and adolescents are based on nationally representative data obtained from five surveys conducted between 1963 and 1994 (cycles II and III of the National Health and Examination Survey and rounds I, II and III of the NHANES).

Prevalence indices describe the proportion of OW children in the population, but provide no information on the extent to which they exceed the threshold. Research indicates that the risks of health problems for adults associated with being OW are increasing in BMI (or in other words, someone who is 50% OW faces greater health risks than someone who is 10% OW).[10–12] For example, the risk of heart failure increases 5% in adult men and 7% in adult women with a unit

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increase in BMI.[11] Similarly, a one-unit increase in BMI is associated with a 6% increase in the relative risks of total, ischemic and hemorrhagic stroke for men.[12] As prevalence indices censor all information about the distribution of BMI, except whether it is above or below the OW cutoff, they mask important information about the extent of the health problem. While research has not directly shown that health risks are also increasing in BMI for children and adolescents, this paper assumes that the evidence for adults warrants concern about the BMI distribution of overweight children. The purpose of this paper is to describe a measure of OW that provides information on both the prevalence and extent (the extent to which BMI exceeds the OW threshold) of child OW. This measure can help to establish whether the prevalence of child OW sufficiently describes the health problem or if there is more to be learned from a measure that is sensitive to changes in the BMI distribution of the OW.

Methods

The data used in this paper are from four rounds of the NHANES, which is conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention. The NHANES samples are representative of the US civilian, noninstitutionalized population, and observations were selected following a stratified, multistage design. Measures of child overweight are estimated at four points in time: 1971–1974 (NHANES I), 1976–1980 (NHANES II), 1988–1994 (NHANES III) and 1999–2000 (2-y cycle NHANES). Anthropometric measures were obtained by trained health technicians, and effective sample sizes of children and adolescents between 2 and 19 y of age range from 4037 in 1999–2000 to 10 590 in 1988–1994 (NHANES III).

To measure the extent of child OW, this paper considers the following index:

$$\mathrm{EOW} = (1/n)\sum_i I(\mathrm{BMI}_i \geq f_i)[(\mathrm{BMI}_i - f_i)/f_i] \qquad (1)$$

where n is the sample size, i subscripts the child, f is the cutoff point identifying who is overweight and I is an indicator function that takes a value of 1 if the statement is true and 0 otherwise. More specifically, the indicator function will take a value of 1 if the child is OW and 0 if the child's BMI is less than the 95th percentile of the sex-specific BMI for age growth charts. This paper also examines children and adolescents who are at risk of being OW, in which case the 85th percentile is used as the threshold value for f_i.

I refer to the term in square brackets, $[(\mathrm{BMI}_i\text{-}f_i)/f_i]$, as the proportionate OW gap because it measures the amount by which each OW child's BMI exceeds their OW threshold, and this amount is expressed as a proportion of the threshold. Examination of this term reveals that EOW treats BMI as a continuous variable for the OW population. It embeds the assumption that public health worsens as average BMI increases in the OW population. This is in contrast to the prevalence measure which views OW as a dichotomous outcome, and is not sensitive to the extent to which the EOW exceeds their threshold. Expressing excess BMI as a proportion of the OW threshold is particularly important for children since the threshold varies by age and sex. The resulting measure, EOW, is the sum of the proportionate OW gaps divided by the sample size, or the sample average value of the proportionate OW gaps. (In the case where BMI is less than the threshold, the indicator function is 0, and so too is the product of the two terms.)

To illustrate this measure, consider, for example, an 8-y-old boy with a BMI of 22. His OW threshold is approximately 20, and his proportionate OW gap is 10%. Consider now another boy with a BMI of 22, but this one is 9 y old instead of 8. This older boy has an OW threshold of about 21 and his proportionate OW gap would be just under 5%. An examination of the prevalence of child OW would register both of these boys as OW, and both would contribute equally to the prevalence measure. In contrast, the EOW measure captures the fact that the 8-y-old boy is more OW than the 9-y-old boy, and thereby provides a measure of the extent of the OW problem. The EOW measure will increase when the prevalence of OW increases, but unlike the prevalence measure, it will also increase when those OW becomes heavier on average.

The usefulness of this measure can further be illustrated by considering an OW person who gains weight. This weight gain has no effect on the OW prevalence, but the health of this person has changed and this change is reflected through an increase in EOW. In terms of describing the magnitude of the public-health problem and in shaping public-health policy, EOW provides important information. For example, consider a hypothetical health policy that focused on helping the extremely OW lose weight. If successful, this policy would result in an improvement in public health, which would be indicated by a lowering of EOW, but there might very well be no change in the prevalence measure.

The average extent of OW for the *entire* population, EOW, when combined with information about the prevalence of OW, additionally provides insight into the extent of OW for the *OW* population. The interpretation of the ratio of EOW to prevalence can be seen by noting that the EOW measure is the sample sum of the proportionate OW gaps divided by the entire sample size, n. The OW prevalence measure can be expressed as the number of OW in the sample, say n_j, divided by the sample size n. Dividing EOW by the OW prevalence results in the sum of the proportionate OW gaps divided by n_j, the sample size of those who are OW. This ratio is then the average proportionate amount by which the OW exceed their BMI threshold.

For example, if this ratio is equal to 0.15 this means that, on average, the OW are 15% percent in excess of their thresholds. Increases in this measure indicate that the OW are becoming increasingly OW on average. As a measure of the public-health problem though (and in contrast to EOW), this measure has the undesirable characteristic that it is not monotonically increasing in BMI. For example, if a child's BMI increases and moves from being classified as not OW to OW, then EOW will increase. The average amount by which the OW exceed their threshold may actually decline though, because this new OW child will likely bring down the average value of excess BMI of the OW. Nonetheless, when combined with information about the prevalence and extent of OW, this ratio readily conveys important information about the BMI distribution of the OW population. It is useful to note that an alternative method of treating BMI as a continuous variable would be to plot out and compare shifts in the BMI distribution over time. A comparison of NHANES II and NHANES III illustrates that indeed the entire BMI distribution appears to be shifted to the right between 1976 and 1994.[13]

Results

Tables 1–4 provide weighted estimates of EOW, the OW prevalence, and the ratio of these two measures. The sample weights reflect the unequal probability of selection resulting from the sample design (including corrections for oversampling) and also correct for nonresponse. All standard errors correct for the stratified and multistage nature of the sample design. Estimates from NHANES I, II and III are based on the NHANES pseudo-strata and pseudo-PSUs.[14] In the case of the NHANES 1999–2000 cycle, no pseudo-design variables are yet available in these files, so the standard errors are derived following the method of balanced repeated replication with Fay's adjustment parameter set to 0.8.[15]

Table 1 presents estimates of OW and at risk of being OW for ages 2–19 y. At risk of OW is defined as having a BMI at or above the 85th percentile of the sex-specific BMI for age growth charts. The estimates are age-standardized by the direct method to the 2000 population estimates to adjust for the changing distribution of age over the decades. The patterns of change for OW and at risk of OW are similar. During the 1970s there was little change, with the OW prevalence around 5% and the at-risk-of-OW prevalence at 15%. During the 1980s and 1990s both measures increased dramatically. By 1999–2000, 14.4% of children and adolescents were OW and 28.4% were at risk of being OW.

While this significant increase in both prevalence measures is alarming, the increase in the extent of OW was larger. Between 1971–1974 and 1999–2000, the OW prevalence increased by 182% while the extent of OW increased by 247%. The increasing extent of OW has resulted both from the increasing prevalence and also from noting that, in 1971–1974, OW children were on average 12% in excess of their thresholds. By 1999–2000, OW children were 14% in excess of their thresholds. The increasing extent of OW indicates that the health risks associated with excess adipose are likely even greater than that indicated by the increased prevalence rates. More children are becoming OW, and these OW children are getting heavier on average.

The same phenomenon is occurring with at risk of OW. The extent of this measure increased at more than twice the pace of the increase in the prevalence rate. Again, this result is driven by both the increasing at-risk-of-OW prevalence and a mean shift in the BMI distribution of the at-risk children. In 1971–1974, those children who were at risk of being OW were on average 12% over their at-risk thresholds (85th percentiles of the sex-specific BMI for age growth charts). By 1999–2000, the at-risk children were on average 18% in excess of their thresholds. The fast-paced growth of

Table 1 OW and at risk of OW, ages 2–19 y

Indices of OW	*1971–1974*	*1976–1980*	*1988–1994*	*1999–2000*	*change: 1971–2000*
Panel A: at risk, ages 2–19 y					
Prevalence	15.3	14.7	23.1	28.4	86%
	(0.65)	(0.53)	(0.98)	(1.27)	
Extent, EOW	1.9	2.0	3.8	5.1	174%
	(0.1)	(0.13)	(0.31)	(0.39)	
Avg. OW gap[1] (EOW/prevalence)100	12%	13%	16%	18%	
Panel B: OW, ages 2–19 y					
Prevalence	5.1	5.5	10	14.4	182%
	(0.3)	(0.38)	(0.58)	(0.71)	
Extent, EOW	0.6	0.7	1.5	2.0	247%
	(0.05)	(0.07)	(0.19)	(0.14)	
Avg. OW gap[a] (EOW/prevalence)100	12%	12%	15%	14%	
Sample size	*7037*	*7349*	*10 590*	*4037*	

[a]Average OW gap is the average amount by which the OW population exceeds the OW threshold, expressed as a percent of the threshold.
Source: NHANES I, II and III, 1999–2000.
Note: At risk of OW is defined as a BMI for age at the 85th percentile or higher, and OW is defined as a BMI for age at the 95th percentile or higher. Indices are multiplied by 100 and estimated with the exam sample weights. Estimates for ages 2–19 y are age-standardized by the direct method to the 2000 Census population using age groups 2–4, 5, 6–8, 9, 10–11, 12–14, 15–17, 18–19 y. Standard errors, in parentheses and also multiplied by 100, are corrected for sample-design effects.

children who are at risk of being OW and the extent of this measure indicates that there is significant risk that the growth in child OW will continue in the near future.

Table 2 examines child OW by three age categories (2–5, 6–11 and 12–19 y). Over each category, the prevalence of OW more than doubled between 1971–1974 and 1999–2000,

Table 2 Child and adolescent OW by age

Indices of OW	*1971–1974*	*1976–1980*	*1988–1994*	*1999–2000*	*Change: 1971–2000*
Panel A: ages 2–5 y					
Prevalence	4.9	5.0	6.9	10.4	112%
	(0.57)	(0.59)	(0.79)	(1.19)	
Extent, EOW	0.4	0.4	0.9	1.0	158%
	(0.06)	(0.05)	(0.27)	(0.13)	
Avg. OW gap[a] (EOW/prevalence)100	8%	7%	12%	9%	
Sample size	*2342*	*3007*	*3858*	*739*	
Panel B: ages 6–11 y					
Prevalence	3.9	6.5	11.5	15.3	293%
	(0.53)	(0.64)	(0.98)	(1.18)	
Extent, EOW	0.4	0.9	1.7	2.0	354%
	(0.08)	(0.13)	(0.18)	(0.21)	
Avg. OW gap[a] (EOW/prevalence)100	11%	14%	15%	13%	
Sample size	*2057*	*1754*	*3515*	*1054*	
Panel C: ages 12–19 y					
Prevalence	6.1	5.1	10.4	15.5	153%
	(0.59)	(0.48)	(0.91)	(0.84)	
Extent, EOW	0.8	0.7	1.7	2.6	220%
	(0.09)	(0.1)	(0.32)	(0.19)	
Avg. OW gap[a] (EOW/prevalence)100	13%	13%	16%	17%	
Sample size	*2638*	*2588*	*3217*	*2244*	

[a]Average OW gap is the average amount by which the OW population exceeds the OW threshold, expressed as a percent of the threshold.
Source: NHANES I, II and III, 1999–2000.
Note: OW is defined as a BMI for age at the 95th percentile or higher. Indices are multiplied by 100 and estimated with the exam sample weights. Standard errors, in parentheses and also multiplied by 100, are corrected for sample-design effects.

Table 3 OW by sex, ages 12–19 y

Indices of OW	*1971–1974*	*1976–1980*	*1988–1994*	*1999–2000*	*Change: 1971–2000*
Panel A: adolescent boys, ages 12–19 y					
Prevalence	6.1	4.8	11.2	15.5	155%
	(0.8)	(0.51)	(01.19)	(01.13)	
Extent, EOW	0.7	0.6	2.0	2.7	293%
	(0.09)	(0.13)	(0.51)	(0.28)	
Avg. OW gap[a] (EOW/prevalence)100	11%	13%	18%	17%	
Sample size	*1324*	*1349*	*1565*	*1155*	
Panel B: adolescent girls, ages 12–19 y					
Prevalence	6.2	5.3	9.7	15.5	152%
	(0.76)	(0.77)	(1.11)	(1.13)	
Extent, EOW	0.9	0.7	1.5	2.5	165%
	(0.15)	(0.15)	(0.25)	(0.24)	
Avg. OW gap[a] (EOW/prevalence)100	15%	13%	15%	16%	
Sample size	*1314*	*1239*	*1652*	*1089*	

[a]Average OW gap is the average amount by which the OW population exceeds the OW threshold, expressed as a percent of the threshold.
Source: NHANES I, II and III, 1999–2000.
Note: OW is defined as a BMI for age at the 95th percentile or higher. Indices are multiplied by 100 and estimated with the exam sample weights. Standard errors, in parentheses and also multiplied by 100, are corrected for sample-design effects.

Table 4 OW by race and ethnicity, ages 12–19 y

Indices of OW	*1971–1974*	*1976–1980*	*1988–1994*	*1999–2000*	*Change: 1971–2000*
Panel A: non-Hispanic white adolescents					
Prevalence	5.7	4.2	9.8	12.7	123%
	(0.63)	(0.47)	(1.25)	(1.2)	
Extent, EOW	0.7	0.5	1.6	1.9	165%
	(0.11)	(0.11)	(0.44)	(0.28)	
Avg. OW gap[a] (EOW/prevalence)100	13%	12%	17%	15%	
Sample size	*1841*	*1954*	*837*	*470*	
Panel B: non-Hispanic black adolescents					
Prevalence	7.6	8.5	14.5	23.6	212%
	(1.56)	(1.4)	(1.02)	(1.45)	
Extent, EOW	1.4	1.3	2.8	5.4	292%
	(0.35)	(0.34)	(0.28)	(0.39)	
Avg. OW gap[a] (EOW/prevalence)100	18%	16%	19%	23%	
Sample size	*618*	*401*	*1134*	*630*	
Panel C: hispanic adolescents					
Prevalence	8.8	9.1	14.2	18.8	113%
	(3.82)	(2.51)	(1.72)	(1.42)	
Extent, EOW	0.8	1.1	2.0	3.0	271%
	(0.45)	(0.43)	(0.31)	(0.31)	
Avg. OW gap[a] (EOW/prevalence)100	9%	12%	14%	16%	
Sample size	*159*	*188*	*1084*	*1080*	

[a]Average OW gap is the average amount by which the OW population exceeds the OW threshold, expressed as a percent of the threshold.
Source: NHANES I, II and III, 1999–2000.
Note: OW is defined as a BMI for age at the 95th percentile or higher. Indices are multiplied by 100 and estimated with the exam sample weights. Standard errors, in parentheses and also multiplied by 100, are corrected for sample-design effects. Sample sizes do not match those in Tables 1–3 because race and ethnicity is missing for some observations (less than 5% of the sample).

with the greatest increase in prevalence for those between the ages of 6 and 11 y. For each age category, the extent of OW increased at a rate faster than the increasing prevalence. The increase in the average amount by which OW children exceed their threshold was relatively small, increasing from 8 to 9% for ages 2–5 y and from 11 to 13% for ages 6–11 y. The largest increase in this measure is for adolescents between the ages of 12 and 19 y. In 1971–1974 (and 1976–1980), OW adolescents were on average 13% in excess of their OW thresholds, and by 1999–2000 this increased to 17%.

Breaking out adolescents by sex provides a further example of the usefulness of examining the extent of OW. The change in OW prevalence between 1971–1974 and 1999–2000 was very similar for male and female adolescents. Both rates were slightly higher than 6% in the early 1970s and both were 15.5% in 1999–2000, suggesting essentially no sex differences in adolescent OW. The measure of the extent of OW, though, reveals that there have been important differences. In the early 1970s, male adolescents had a lower extent of OW than female. An implication of this is that in 1971–1974, OW male adolescents were on average 11% in excess of their OW threshold, while OW female adolescents were much more OW on average (15% in excess of their thresholds). By 1999–2000, this sex difference vanished and OW adolescent boys were slightly more OW than adolescent girls. This relative change in the sex distribution of the extent of OW is readily observed by noting that the growth rate of EOW for adolescent boys was 293% compared to 165% for adolescent girls between 1971–1974 and 1999–2000.

Table 4 provides a final example of the additional information gained from the measure of the extent of OW. An analysis of the prevalence of adolescent OW by race and ethnicity indicates that non-Hispanic blacks have the highest prevalence (23.6%) with a rate that is just less than twice the rate for non-Hispanic whites (12.7%). The measure of the extent of OW for non-Hispanic blacks is more than 2.8 times the measure of extent for non-Hispanic whites. These measures reveal that OW non-Hispanic blacks are on average 23% in excess of their OW threshold, while this figure for non-Hispanic whites is much lower at 15%. The OW prevalence measure indicates that this health problem is more pervasive for non-Hispanic blacks than for Hispanics and non-Hispanic whites, and the measure of the extent indicates that the health issues associated with being OW are likely to be more severe for non-Hispanic blacks.

Conclusion

This paper examines children and considers a measure of OW that is sensitive to both changes in the prevalence of

OW and also to changes in the BMI distribution of the OW. This measure, EOW, is referred to as the extent of OW because it measures the average amount by which the population exceeds the OW threshold. While previous research has shown that the prevalence of child OW has increased between 1971–1974 and 1999–2000, the extent of OW has been increasing at a faster rate. In other words, not only has the proportion of OW children been increasing, but it is also the case that OW children have been getting steadily more OW. The extent of child OW has been increasing faster than the prevalence of child OW for all classifications considered in this paper, including the analysis by age, sex, race and ethnicity.

Research indicates that health risks for adults are increasing in BMI and therefore shifts in the BMI distribution of OW adults have important health implications. The research in this paper indicates that there have been large shifts in the BMI distribution of OW children that the OW prevalence does not fully reveal. This finding suggests that future research into the health consequences of child and adolescent OW would add useful insights by examining whether health risks for children are increasing in BMI, as they are for adults. If this is the case, then the implication of the results in this paper is that the public-health problem of child OW is even greater than that revealed by the increasing OW prevalence rates.

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